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Thank you for your assistance.
Prolegomenon to norms in branching space–times

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ARTICLE INFO

Article history:
Available online xxxx

Keywords: ???

ABSTRACT

Earlier (collaborative) work postulated that agency is essentially indeterministic, and finds a home in “branching times” (BT). BT is built on world-wide but momentary events called “moments” structured by an indeterministic causal ordering. The notion of a “history” is defined as a suitable chain of moments; histories branch one from another at moments. Other earlier work, the essential points of which are summarized in Section 2, led to “branching space–times” (BST). BT moments are replaced in BST by local “point events,” and “histories” are redefined more realistically as a family of suitable space–time-like structures that branch from one another at point events. In BST one finds that “transitions” from initial events to outcome events—each properly defined—play a fundamental role as originating causes (causa causantes) and effects. This spatio-temporal-causal story provides, in Section 3, an objective foundation for an indeterministic theory of agents and choices amid BST (BSTAC), the key concepts of which are “life event,” “life history,” and “person,” the latter essentially involving alternate possibilities, some of which arise from free choices. Section 4 works out a concept of “choice point,” leading to a BST account of “agent $\alpha$ sees to outcome $O$,” which is more sophisticated than the stit concept of earlier work. Many-agent cooperation is considered in Section 5, with hints concerning message sending and receiving. A theory of norms in BST (BSTACN) that builds on the foregoing, and also on earlier work, is briefly adumbrated in Section 6.

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1. Norms and agency

The idea of norms presupposes agency, and agency presupposes an indeterministic causal order. This has been, of course, a far from universal opinion since philosophers such as Kant and Hume, each in his own way a strict deterministic, populated the world with so-called “compatibilists,” meaning those who believe that agency is compatible with (or even requires) determinism. Naturally this dialectical situation has given rise to “incompatibilism,” where what is at stake is compatibility/incompatibility with determinism. It is no surprise that arguments one way or the other generally turn out fruitless. A good way of avoiding this particular knot is to shift focus to the question of the compatibility between agency and indeterminism, or even more interestingly, to plunge ahead under the belief that agency presupposes indeterminism in the causal order.

This stance, which lines up with that of Kane [14], is taken by Belnap et al. [9] (Facing the future, henceforth FF), which concentrates on agents in so-called “branching time” (BT). FF discusses at length how agency fits into and is illuminated by BT, arguing that the rudiments of indeterminism as required by agency are well-modeled by BT. Branching time is not, however, a comfortable background for stating the doctrine that agency presupposes indeterminism in the causal order.

© Thanks to Thomas Müller for many corrections and comments. His is the eye of an eagle. Two helpful referees each made suggestions that I have been pleased to use.

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its own causal future. The wording of this doctrine as "no action at a distance" makes it clear how alien it is to branching
time, which has no concept of concept, nor even the much more modest concept of "over there." That doctrine can only be
stated and understood in the context of a causal order that, unlike branching time, supports the idea of "over there," which
the jargon of Special Relativity calls "space-like relatedness." A causal order admitting both indeterminism and space-like
relatedness is well-modeled, up to an approximation, in "branching space–times," henceforth BST, as defined in Belnap [1].
In the normal case, space-like relatedness of choice events guarantees that the choices are independent (not correlated).
The abnormal, even weird, case of space-like related choices that are nevertheless correlated is called "funny business"; it is
investigated in Belnap [3, 5], and Müller et al. [22]. How causes, in the guise of causeus causantes, or "originating causes," fit
into BST, provided there is no funny business, is developed in Belnap [7]. We may take over a good deal of that theory
if we identify free choices as among the originating causes in BST. From now on, I'll drop "free" as redundant, in the belief
that so-called "Frankfurt cases" equivocate: Given that we suppress vagueness as a red herring, something called a choice is
either free, or it's not really a choice. The identification of choice and free choice ensures the principled propriety of claiming
that certain choices are entirely independent. To this end, we'll outline the beginnings of a theory of "branching space–times
with agents and choices" (BSTAC), using previous work as much as possible. We aim for a mathematically rigorous theory;
as a consequence, the theory necessarily avoids the typical waffling about agency with mental concepts, and as such does
not pretend to offer a "complete" story.

2. Rudiments of the theory of branching space–times

One way of understanding the aim of BST is by thinking of it as arising by two independent moves from Newtonian
theory, a theory that is both deterministic and non-relativistic. Move 1: "Branching time" theory comes from the Newtonian
basis by replacing determinism with indeterminism, while still being non-relativistic. The "world" of branching time is
composed of "moments" in a tree-like arrangement, with each complete branch counting as a possible "history." It is critical
that each moment should be pictured as a "simultaneity slice" existing straight across the entire universe, "edge to edge,
so to speak. The picture of a history as a linear order of spatially wide instantaneous events violates the relativistic principle
that there is no absolute meaning to simultaneity. Furthermore, in branching time, a branch point between two histories
is the entire "simultaneity slice," so that this "all at once" branching, involving, for example, simultaneous branching in
Chicago and at a chosen spot on the surface of Neptune, looks to be a serious violation of the relativistic prohibition of
"action at a distance." Move 2: The core idea of Special Relativity comes from the Newtonian basis by retaining determin-
ism, while replacing global influences (action at a distance) with relativistic only-local influences. The "world" of Special
Relativity is composed of "point events" in a four-dimensional "space–time" based on a causal ordering. The causal future
of a point event is restricted to the forward light cone determined by the causal order, and, symmetrically, the causal past
is confined to the backward light cone. Finally, the theory of branching space–times is intended to be both indeterministic
and relativistic: Many possible histories branching each from each, with each history being a relativistic space–time. Both
the indeterminism and the relativity ingredient in the theory of branching space–times are intended as "pre-physics"; for
example, no probabilities and no frames of reference—indeed, no numbers. The aim here is to highlight deep features of
these theories by suppressing the serious physics and the numbers that they require. In order to avoid both the forbidden
notion of absolute simultaneity and also “action at a distance,” the branching between two space–times must occur at a
point event. It seems clear that a good theory of branching space–times does not at once come to mind.

The primitives of BST are two: (1) Our World, abbreviated OW, is intended to be a set of "concrete possible point events"
(or just "point events") e ∈ OW, and (2) <, the "causal order" on OW. The causal-ordering relation e₁ < e₂, which has both
spatio-temporal and modal significance in BST, may be read as either "e₁ is in the settled causal past of e₂" or "e₂ is in
the future of possibilities of e₁." It is assumed that < is a strict partial order on OW with no maximal elements. Where a
chain is a subset of OW such that two distinct members are always comparable by <, an outcome chain, O, is a nonempty
lower bounded chain, and it is assumed that every outcome chain has an infimum. A history, h, is a maximal directed set,
where a set is directed if it contains an upper bound for each pair of its members. An initial chain, I, is nonempty and upper
bounded, and it is assumed that every initial chain has a supremum in every history that contains it. Fact: Under the causal
ordering, histories are closed toward the past (if two histories overlap at a point event, they share the whole causal past
of that point event). H is a set of histories (also called a proposition). There is also a postulate saying that given two initial
chains and two histories, the order of the respective suprema is preserved as the histories are varied. But far and away the
most distinctive assumption is the "prior choice postulate," which says that every contingent outcome has an originating
cause in its past:

Prior choice postulate. Let O be an outcome chain, and let O ⊆ (h₁ – h₂). Then there is a point event e in the causal past of every
member of O such that e is maximal in (h₁ ∩ h₂).

These postulates taken together yield "BST," the theory of branching-space times according to Belnap [1].

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1 There are in the literature several candidates for BST theory and several developments thereof. Consult in particular the works of Kowalski and Müller
and Placek and Weiner listed in the references. Of special note are their contributions to the theory of probabilities in BST, to the theory of counterfactual
conditionals in BST, and to the application to certain problems in quantum mechanics.
The prior choice postulate leads to a certain concept of causes in branching space–times called causae causantes studied in Belnap [6] (henceforth CC). I have to go through some technicalities to get there, so that it will be good to keep in mind the relevant concept of causation at which we are aiming. It comes from the work of Mackie [18]. There Mackie develops an idea which has become well known: the idea of a cause as an “INUS condition,” using an acronym for “Insufficient but non-redundant part of an unnecessary but sufficient” condition (think constituent of a disjunctive normal form). An important difference is here, in contrast to Mackie, I develop a rigorous theory of causes and effects as certain kinds of events (rather than propositions) in BST. Here is a bare-bones sketch:

1. \( H_0 \) is the set of all histories overlapping \( O \); it represents as a “proposition” \( O \)’s beginning to be, which is the way that outcome chains “occur” in a history.

2. \( H_e \), the set of all histories to which \( e \) belongs, is the proposition that \( e \) occurs, \( h_1 \equiv_e h_2 \) is read “\( h_1 \) is undivided at \( e \)” from \( h_2 \), and is provably an equivalence relation on \( H(e) \). The induced partition of \( H(e) \) is written \( P_e \), with \( P_e(h) \), for \( e \in h \), being the member of \( P_e \) to which \( h \) belongs. The idea of \( P_e \) is essential to BST theory. When a set of histories, \( H \), belongs to \( P_e \), it is proper to understand \( H \) as an elementary possibility at or immediate outcome of \( e \). Of course one case, the uninteresting case, is that \( H = H(e) \), making the partition trivial. In the nontrivial case, if \( H_1, H_2 \) are distinct members of \( P_e \), they must be disjoint, which is to say, inconsistent: \( e \) is then said to be a choice point; in this case, if history \( h_1 \in H_1 \) and history \( h_2 \in H_2 \), we write \( h_1 \perp h_2 \) to say that the two histories “split” at \( e \); Before and at \( e \), both histories are possible (\( e \) belongs to both histories), but at any point event after \( e \), at most one is possible (no point after \( e \) belongs to both histories). Splitting at choice points is how Our World counts as being a world of “branching histories.”

3. “Transition events” are of central importance in the BST theory of causation. Defining a scattered outcome event as a set, \( O \), of outcome chains all of which overlap some one history, and defining an initial event, \( I \), as a nonempty subset of some one history, a transition event is defined as an ordered pair, written \( I \to O \), such that \( I \) precedes \( O \) in the causal order in an appropriate sense: Every point event in \( I \) properly precedes some chain in \( O \). The entire theory can be generalized by taking outcomes of transitions as “disjunctive outcome events,” represented by a set of pairwise inconsistent scattered outcome events; and it can be specialized by restricting attention to “chain” outcome events.

4. Even more specialized are the crucial basic transitions that are at the bottom of BST causal theory. They can be represented as point-event/outcome-chain transitions (\( e \to O \)), where \( \inf(O) = e \), or as point-event/outcome-proposition transitions (\( e \to P_e(h) \)), where \( e \in h \). The two representations turn out to come to the same thing. In either case, a basic transition is from a point event to an immediate outcome of \( e \). Such transitions are the ultimate, uncaused originating causes, the causae causantes.

5. But causes of what? The simplest to explain is causation of an outcome chain, \( O \). When a contingent outcome, \( O \), occurs, we should always look for an event in Our World where things could have gone either way, either ruling out \( O \) altogether, or keeping it possible. In BST terms, that means looking for a point event, \( e \), at which there is a split between some history excluding \( O \) entirely and the histories \( H_1 \), in which \( O \) begins to be: \( h \perp H(1) \) for some \( h \). The prior choice postulate guarantees that we shall find at least one such in the past of contingent \( O \).

6. Such an \( e \) is a basic cause-like locus for \( O \). It turns out, however, that the theory of basic cause-like loci is not easily understood in the absence of an additional postulate, the so-called “no funny business” postulate, which we therefore assume. The postulate simply says that all cause-like loci for \( O \) lie in the past of \( O \). I therefore let \( pcl(O) \) be the set of past cause-like loci of \( O \). We might call the resultant theory simply BST + NFB; for the duration of this essay, however, we use plain “BST” as short for “BST + NFB.”

7. But which of the many basic outcomes of a past causal locus of \( e \) should be considered in defining the idea of a causa causans of \( O \)? If there were funny business, that question might be difficult, but as it is, since \( e \) is in the past of \( O \), we can calculate that the occurrence of \( O \) is consistent with (i.e., has a history in common with) exactly one basic outcome of \( e \). Let us give it a name: Provided \( e < O \), define \( P_e(O) \), read “the projection of \( O \) onto \( e \),” as the unique member of \( P_e \) that is consistent with \( H(e) \).

8. Finally, define \( cc(O) \), the set of causae causantes of \( O \), as \( \{e \in pcl(O) \mid e \in P_e(O)\} \); that is, as the set each member of which is a nontrivial basic transition with initial \( e \) whose outcome is precisely the projection of \( O \) onto \( e \).

9. This story generalizes, the most general concept being the set \( cc(I \to O) \) of causae causantes of a transition event with initial, \( I \), and disjunctive outcome, \( O \). Details, necessarily omitted here, are all to be found in CC. The critical upshot is that the full set of causae causantes of an outcome event or a transition event is provably always a full set of INUS conditions of the event in the sense of Mackie [18], where, to repeat, an INUS condition is an insufficient but non-redundant part of an unnecessary but sufficient condition. The causae causantes as a whole give the complete objective causal story in terms of events that describe the “why” (or perhaps the “how”) of the outcome or transition event.

10. The concept of a scattered outcome event, \( O \), is intermediate between that of a chain outcome, \( O \), and a disjunctive outcome, \( O \). The scattering can be either space-like or time-like. Being non-disjunctive, a scattered outcome event, \( O \), or transition event \( I \to O \), like a chain outcome, \( O \), will have a set of causae causantes that are to be taken non-disjunctively, not as a set of INUS conditions, but instead as a set of “INNS” conditions, each of which is an insufficient but non-redundant part of a necessary and sufficient condition. Some of the most influential literature on causation either confuses INUS and INNS conditions, or, more likely, gives an only informal and partly subjective account of the difference.
That may seem complicated, but I think that nothing less complicated will do if what is wanted is an objective and rigorous theory of causation in the events.

3. Agents

FF took the basic locution of the theory of agents and their choices to be \([\alpha \text{ stit } Q]\), read "\(\alpha\) sees to it that \(Q\)." There was no separate theory of agents independent of this location. As a consequence, in FF, based as it was on branching time, and with explicit refusal to import any "mental" concepts, there could be no direct analysis of "the real internal constitution" of an agent. Instead, a nonempty set called \(\text{Agent}\) was postulated, members of which were characterized only indirectly, by reference to, so to speak, what they objectively did or might have done, or might do.

3.1. The representation of the agent

Here I outline a theory, "BSTAC," of how agents and choices fit into branching space–times. Even though the name doesn’t suggest, BSTAC is intended to be limited by the inclusion of a "no funny business" postulate. Because BST takes \(\text{OW}\) to be based on point events instead of moments (which, recall, are instantaneous in time, but maximally spread out in space), something more can be said about the inner structure of an agent.

The simple idea is to adapt the theory of agents to the chief difference between non-relativistic branching time and relativistic branching space–times, namely, the difference between what “the causal order relation” relates. The critical feature of agents in branching time is that moments are super-events taken to be "spatially" rich enough to be "occupied" by more than one agent. That in turn calls for a BT-stit postulate insuring that the simultaneous choices of distinct agents must necessarily be independent. There can be no "influence" of the choice of one agent at four o’clock sharp on the choice of another agent at exactly that same time. To suppose the contrary is to suppose a form of "action at a distance," and to become involved in pointless muddles, perhaps involving some confused idea of "common cause" that is not relevant to (free) choice.\(^2\)

Branching space–times theory, however, postulates point events instead of moments. Point events would seem to be so small as to admit the "presence" of at most one agent. Perhaps for modeling some weird scenarios one might wish to play with "double occupancy," but it is a byway that at this point is best left unexplored.\(^3\) For this reason it seems reasonable to begin by representing an agent as a set of point events, the set of point events that may be thought of as possibly occurring in the course of his or her life. (For reasons given at the end of the discussion below of the "External standpoint," it is better to think this way instead of copying branching-time theory by thinking of the point events as "locations" of the agent.) In contrast, in branching time it would make no sense at all to represent an agent as a set of moments! Continuing to use \(\text{Agent}\) as the set of agents, we may therefore begin with a simple assumption.

**Postulate 1 (Representation of the agent).** Every agent, \(\alpha \in \text{Agent}\), is a nonempty set of point events in OW: \(\forall \alpha (\alpha \in \text{Agent} \rightarrow \emptyset \neq \alpha \subseteq \text{Our World})\).

I hope that it is clear that I intend Postulate 1 as a representation of agents, not as an account of what agents “really are.”

3.2. Standpoints

To make further sense, it is essential to assume a “standpoint.”

3.2.1. External standpoint

We may take ourselves for present purposes to be taking a “godlike” or “scientific” or “external” standpoint entirely outside of Our World. In this case all point events are on a par: All are mere possibilities, and we are not entitled to use either tense expressions or differentially applicable modal expressions. From the external standpoint, each member, \(e\), of \(\alpha\) represents one of \(\alpha\)'s possible (point-like) life events. For mere brevity, I usually drop “point like.” Perhaps this is an expository mistake, given that I certainly wish to leave theoretical room for extended life events. The shorter phrase should, however, work for this essay. We may say if we like that all point events (hence all of \(\alpha\)’s possible life events) "are equally real," as is sometimes said with reference to the Everett interpretation of quantum mechanics; but it must be borne in mind that their "reality" is the reality of mere possibilities. From the envisioned standpoint, it makes no sense to distinguish two kinds of point events, the “possible” and the “actual,” much less three kinds, including the “impossible.”

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2 The postulate works to keep the BT-stit theory out of trouble, but it is after all just wrong to think that choices of agents operating jointly should occur at exactly the same moment. A reason to move from BT to BST was precisely to avoid “trouble” without the wrongness. Section 4.1 calls the BT postulate “ludicrous.” It must be observed, however, that BT itself seems to have the resources causally to combine successive choices by one or more agents by applying to BT the ideas of cause causantes as transitions—a thought that is not new, but since not having been worked out in detail, has heretofore been expressed only in conversations.

3 Later we enter Postulate 5, which asserts that “double occupancy” doesn’t happen. Please cite this article in press as: N. Belnap, Prelegomenon to norms in branching space–times, Journal of Applied Logic (2011), doi:10.1016/j.jal.2009.05.005.
Nevertheless, the external standpoint welcomes relational versions of possibility, actuality, and impossibility of point events. To say that a point event, \(e_1\), is (1) possible or (2) actual or (3) impossible relative to \(e_0\), is simply to say that (1) some history contains both \(e_0\) and \(e_1\), or (2) that every history containing \(e_0\) also contains \(e_1\) (that is, that at \(e_0\) it is settled that \(e_1\) occurs), or (3) that no history contains both \(e_0\) and \(e_1\).

In a useful analogy, if (1) we take up a standpoint that is not itself located on the surface of planet Earth, then (1a) to say, relationally, that “\(e\) is to the north of \(b\)” is sensible, but (1b) it makes no (ordinary) sense to use “is to the north” as a one-place predicate. If, however, (2) we ourselves are located on the surface of planet Earth, then the context of utterance supplies an otherwise missing second argument to the use of the one-place predicate, “is to the north.” As a corollary, if (1) we take up a standpoint external to Our World, then (1a) relational “earlier/later,” and “space-like related” between pairs of possible life events still make sense, but (1b) one-place “past/present/future/over-there” make no sense. Only when (2) we take up a standpoint in Our World do the latter phrases make sense, provided they are understood as context-dependent.

(Shades of McTaggart!) From such a “godlike” or “scientific” standpoint, when \(e \in \alpha\), we may say, in a strictly technical voice, that the point event \(e\) is part of the agent \(\alpha\). One might also say that \(\alpha\) is located at or occupies \(e\), but it is much better to say that \(e\) is one of \(\alpha\)’s possible life events. The reason is that “location” suggests a position concept, but whereas a point event, \(e\), may have a position in OW, it is not a good idea to say that \(e\) is a position. After all, a central idea is that two radically incompatible point events, each in a distinct possible future of some chance event, may occupy the same spatio-temporal position. Further, invoking the ordering relation, we may say that when \(e_0 < e_1\), either that \(e_0\) is in the causal past of \(e_1\), or that \(e_1\) is in the (causal) future of possibilities of \(e_0\), since these phrases are tenseless and modally constant.

3.2.2. Internal standpoint

We may instead take ourselves to be located at some point event (paradigmatically the one to which “here-now” refers) in Our World. This is most easily viewed through the lens of language, and so, idealizing, you should envisage the point event as the point-event of utterance, or the context-of-utterance point event. In this case, the fundamental “truth” location should be

\[ S, I, e_\epsilon, e, h \models A, \text{ read as} \]

- \(A\) is true with respect to structure \(S\), interpretation \(I\), point event of utterance \(e_\epsilon\), point event \(e\), and history \(h\).

Here \(S\) lists the structure parameters, especially a domain of quantification and the structural elements OW and \(<\), but room is left for space–time structural elements such as a “frame of reference.” \(S\) may itself be called the structure parameter. \(I\) is the interpretation parameter whose job is to interpret the atomic pieces of the language, \(e_\epsilon\) is the point event of utterance, \(e\) is the point event of evaluation (an auxiliary parameter moved by tenses), \(h\) is the history of evaluation (moved by the “settled true” construction), and \(A\) is the sentence to which parameter-dependent truth is attached. I skip the details, except to emphasize that the causal future tense requires that, at a minimum, truth be relativized to a point event, \(e\), and a history, \(h\), that contains \(e\). How this should go can partly be inferred from Chapter 8 of FF, mutatis mutandis. See also the use of “double time references” in Section 6 below; and for a general account of parameterized truth, see Belnap [8].

3.3. Agents and world lines

Given that we represent an agent, \(\alpha\), as a set of point events to be thought of as \(\alpha\)’s possible life events, what constraints make sense? In the beginning it seems best, since easiest, to think of the life of an agent in a particular history as a portion of a “world line.” In other words, for each history, \(h\), if we take the set of those of \(\alpha\)’s possible life events that occur in \(h\), they form a linear order, stretching from \(\alpha\)’s birth to \(\alpha\)’s death in \(h\), each causally comparable with each. (Whether it counts as a fault or not, I confess little or no interest in imaginative speculations concerning a “personal split” within a single, consistent course of events; within, that is, a single space–time.)

Postulate 2 (Agents and world lines). The portion of the life of an agent in a particular history is a chain of point events: \(\forall \alpha \forall h \left[ (\alpha \in \text{Agent} \land h \in \text{Hist}) \rightarrow (\alpha \cap h) \text{ is a chain in Our World} \right]. \) If \((\alpha \cap h) = \emptyset\), we may say that \(\alpha\) “doesn’t exist” in \(h\). For each agent, \(\alpha\), and history, \(h\), we call the set \((\alpha \cap h)\), provided it is nonempty, the life history of \(\alpha\) in \(h\), and therefore a possible life history of \(\alpha\).

Postulate 2 is at this stage of sophistication a natural and helpful postulate, but it is as well to recognize that in a longer run it is likely to be a drastic simplification of the notion of life history. I hope it is needless to say that I am claiming for this postulate only that its simplicity makes it a good beginning; it may well turn out to be useful to represent an agent in a single history as a cloud of point events rather than as a chain. Our chain representation rules out, for instance, that distinct bodily point events count as distinct parts of a life history, since many such points are space-like related and accordingly...
break linear order. Let us, however, leave bodily parts for another day. The thought is that Proposition 2 supplies a useful and manageable first approximation.

It follows at once that \( \alpha \) is a tree. That is, \( \alpha \) is partially ordered by \( < \) (since \( \alpha \) is a subset of OW), and \( \alpha \) satisfies no backward branching (that is, it’s false that for some \( e_0, e_1, e_2 \in \alpha \), \( e_0 < e_2 \) and \( e_1 < e_2 \), but neither \( e_0 < e_1 \) nor \( e_1 < e_0 \). For suppose \( e_0, e_1, e_2 \in \alpha \), and \( e_0 < e_2 \) and \( e_1 < e_2 \). \( e_2 \) must belong to some history, say \( h \), and therefore \( e_0, e_1 \in h \) by downward closure of histories. Hence \( e_0, e_1 \in (\alpha \cap h) \), and since \( (\alpha \cap h) \) is a chain, either \( e_0 < e_1 \) or \( e_1 < e_0 \).

Next, following out an intuition that goes back at least to [16], we assume that each agent has a unique birth event, and in each history a unique death event.

**Postulate 3 (Birth and death of agents).** If \( \alpha \) is an agent, there is a historically (or modally) unique point event that is least among all members of \( \alpha \). This we call the birth of \( \alpha \). Furthermore, for each history, \( h \), such that \( \alpha \cap h \neq \emptyset \), the life history of \( \alpha \) in \( h \) has a maximum (a unique greatest member). This we call the death of \( \alpha \) in \( h \).

On this construction, the death of \( \alpha \) in \( h \) is a “life event” of \( \alpha \); not only does that seem technically harmless, but informally both birth and death are often listed as events in the life of an agent.

The asymmetry in the representation of birth and death does not come from casual English, which, given an event, \( e \), in the actual life of, say, Alexander Hamilton, is equally happy with alternative possible futures vs. alternative possible pasts of \( e \). The former sensibly underwrites alternative possible death events, \( d_1 \) and \( d_2 \), of Alexander Hamilton, but BSTAC properly forbids the latter, which would underwrite (distinct) alternative possible birth events, \( b_1 \) and \( b_2 \). (Evidently the least member of a tree must, if it exists, be unique.)

Is it a strength or a weakness of BSTAC that it makes impossible that Hamilton was born earlier or later than he in fact was? There is no doubt that in BSTAC, if we take “Alexander Hamilton” to name a particular agent, then Hamilton’s birth event is modally fixed. On the other hand, nothing so far laid down prohibits the development of a disjunctive concept of an agent with different birth-events for each component. How that would go I do not know. I suspect that opening up the theory in this way would lead to loose talk; but that is only a suspicion.

I also assume that the life history of each agent in each history is continuous:

**Postulate 4 (Continuity of life histories).**

1. The causal ordering relation is dense in each life history of each agent: For \( e_0, e_2 \in (\alpha \cap h) \), if \( e_0 < e_2 \), then there is a point event \( e_1 \) in \( (\alpha \cap h) \) such that \( e_0 < e_1 \) and \( e_1 < e_2 \).

2. For each agent, \( \alpha \), and history, \( h \), if \( E \) is a subset of the life history of \( \alpha \) in \( h \), then the infimum of \( E \) belongs to that life history, and so does the supremum of \( E \) relative to \( h \). (No jumps or gaps.)

This is perhaps more “metaphysics” than we need, but it makes our representation of agents easier on the imagination. It is easy to become confused when speaking of persons (agents) against a background of indeterminism such as is coded into branching space–times. It helps to remain aware that an agent is represented at three levels.

3.3.1. Summary of three levels

1. A possible life event. We may say that \( e \) is a point event in \( \alpha \) iff \( e \in \alpha \) (where \( e \) is a point event in OW and \( \alpha \) is an agent in Agent).

2. A possible life history. We may say that a subset \( E \) of OW is the possible life history of \( \alpha \) in \( h \) iff \( E = \alpha \cap h \). By natural quantifications, one may speak of “\( \alpha \)’s possible life histories in Our World,” and the “possible life histories of agents in \( h \).”

3. An agent (or a person). \( \alpha \) is an agent iff \( \alpha \in \text{Agent} \), and hence \( \alpha \subseteq \text{OW} \). On this representation, each alternate life history is a literal part of the agent. In slightly looser language, we might say that alternate possibilities are ingredient in the very nature of the agent. This is to be understood in a sense consistent with the doctrine that some causae causantes of a life event of agent \( \alpha \) may be extrinsic to \( \alpha \), as we see in Section 3.4 below.

All of this is from the external point of view. From that standpoint, “possible” draws no distinction. For that reason, we can, if we like, omit “possible” from “possible life event” and “possible life history” without doing much harm.

It is evident that the critical difference between (1) a life history of an agent and (2) an agent is this: Only an agent contains not just choice points, but also the multiple jointly inconsistent but individually possible outcomes of choices sharing a given choice point as initial. Put from a certain internal standpoint, thus is enabled “She chose to walk over the bridge, but if instead she had chosen to run, she would have arrived in time.” No single life history can ground such a story.

When we are anchored to some particular context of utterance, \( e \), we may speak of “the actual past life history of \( \alpha \)” and “the future (portion of the) possible life histories of \( \alpha \)” etc. “Actual” and “past” and “future,” when not explicitly relational, require anchoring to a context of utterance, and you may not use them if your standpoint is external—unless you are prepared to meet the “no thin red line” arguments of Chapter 6 of FF.
3.4. Branching of life histories

Next I explore branching of the life histories of an agent, α.

I’ve idealized a possible life of an agent as a kind of spatio-temporal “worm” in a history. This representation is familiar since each individual history is supposed to be a space–time, and for a very long time philosophers—and often scientists—have played with the worm picture. We then saw that the representation of each possible life history as a chain or worm implies that the agent as a whole has the shape of a tree (no downward branching). It is tempting to leap to the conclusion that each branching of the life histories of an agent, α, represents a decision point for α, but that would be wrong. BST theory is more subtle than that. What is true according to the theory is the “prior choice postulate,” according to which if some life event, e₁, for an agent, α, occurs in one history, say h₁, but not in another history, say h₂, then there is in the past of e₁ a (possibly metaphorical) “choice point,” e₀, which is a branch point in the sense of being maximal in the intersection h₁ ∩ h₂ of the two histories. There is no warrant, however, for believing that e₀ is one of α’s life events, or indeed is a life event of any agent whatsoever. The indeterminism might be resident instead in some thoroughly non-agentive event such as a fair toss of a coin or, perhaps, a choice point between spin-up and spin-down for some electron.

It remains true that a representation of an agent, α, must look a lot like a tree, but α’s tree will in general have two quite different kinds of branching. Which kind will depend on whether the indeterminism represented by the branching is a choice in the life of α, or whether instead the locus of the indeterminism is foreign to α. In both kinds of branching, there is a single past-pointing worm-like representation of the past life of α up to the branching, and an entire assemblage of distinct worm-like representations of the possible future-lives of α subsequent to the branching, severally distributed among the histories in which the life of α continues.

More specifically, let α exist in both of two histories, h₁ and h₂, but with different deaths. In other words, let (α ∩ h₁) ∈ (α ∩ h₂) ≠ ∅ and (α ∩ h₁) ≠ (α ∩ h₂). Since histories are closed backward, the intersection (α ∩ h₁ ∩ h₂)—call it E₀—must be a nonempty backward-pointing tail running from immediately below the branching clear back to the birth of α. Let E₁ be the chain (α ∩ h₁ − h₂), and let E₂ be the chain (α ∩ h₁ − h₂). L₁ = (E₀ ∪ E₁) and L₂ = (E₀ ∪ E₂), being respectively (α ∩ h₁) and (α ∩ h₂), must each be a chain running from birth to death. By continuity and Dedekind, either (1) E₀ has a maximum, e₀, or (2) each of E₁ and E₂ has a minimum, respectively e₁ and e₂. In case (1), one can show that not only is e₀ a choice point for the chains L₁ and L₂, but e₀ can also be shown to be a choice point for h₁ and h₂, that is, a point event maximal in h₁ ∩ h₂. In this case, since e₀ ∈ α, we are entitled to attribute the split between h₁ and h₂ to the agency of α, at least in part (there may be other maxima in (h₁ ∩ h₂)). In case (2), however, the minimum e₁ of E₁, which is in h₁ − h₂, must be a supremum of E₀ ∩ h₁, and symmetrically the minimum e₂ of E₂, which is in h₂ − h₁, must be a supremum of E₀ ∩ h₂. So E₀ must have two (distinct) history-dependent suprema, one in h₁ only, and the other in h₂ only. These two suprema, being as close as they are to E₀, that is, each with nothing in between, must themselves be vanishingly close to each other. Although OW is topologically a T₁ space, e₁ and e₂ testify that OW is not a T₂ space; that is, OW is non-Hausdorff and thus explicitly not a manifold. If one had a doctrine of “space–time positions,” e₁ and e₂ would have to occupy the same space–time position, differing only modally by being in different histories.⁵

This representation of agency in branching space–times presupposes continuity of each space–time. How best to represent agents-in-branching-space–times discretely, as is perhaps required for computer applications, is open for research.⁶ But just as computer representations of real arithmetic must in some way answer to “real arithmetic of the reals, so any such discrete representation must in the end answer to Our World as a BSTAC.

4. Choices

At this point we have a theory of pcls and cause(s causantes) from Section 2 and a theory of agents from Section 3. (Recall that a “pcl” or “past causal locus” of O, is a point event in the past of O at which one possible immediate future of e is consistent with the proposition that O occurs, whereas the rest of the possible immediate futures of e are inconsistent with the occurrence of O.) These analyses leave us little option for an analysis of a choice point for an agent, α, relevant for an outcome, O; namely,

Definition 1 (Choice point, favoring).

(1) e is a choice point for agent α relevant for outcome O if e is a life event of agent α that is a past causal locus of O; that is, e ∈ (α ∩ pcl(O)).

(2) Provided e is a choice point for α relevant for O, (e → Π(O)) is a choice by α that favors O.

(3) A life history of α is relevant for O if some life event of that life history is a past causal locus of O.

⁵ Please do not infer that OW is a weird space–time. It is not, of course, a space–time at all, neither branching nor non-branching; it is, in intent, an assemblage of space–times that branch one from another, the branching being modal rather than spatio-temporal. Earman [12] endorses “ensemble” branching in contrast to “individual” branching. Since Earman, however, loads his phrase with a special meaning, it seems best to avoid “ensemble” in favor of “assemblage.”

⁶ I say “perhaps” because the continuity of each space–time by no means demands that every model admit an infinity of agents or of cause(s causantes), much less a continuum of such.
All this is spoken from an external standpoint. Observe that the choice is a transition event, that is, an ordered pair satisfying certain conditions. Why a transition event? Well, an initial event does not do justice to the idea of choice, because no outcome of the choosing is specified. If you are on the verge of deciding to turn left, you are also (say) on the verge of deciding to turn right, so being "on the verge" cannot count as the choice. So also an outcome event, you having decided to turn left, although a better candidate (since its infimum must be the initial of the choice), does not on the face of it represent the particular, concrete indiscernibility between (say) turning left and turning right that is certainly part of the choice. Realization of a choice ought to represent both the undecided initial and the result of the decision; that's why it is represented as an ordered pair of initial and outcome. In other words, at any time up to and including (say) t, there is more than one possibility for the future, and at any time after t the choice has already been made; so when was the choice? You need both a "before-and-up-to t" with no-choice-yet, and an "after t" with choice-has-been-made; that is, you need a transition. A lot less ink would be spilled on the concept of choice if this were recognized as a truism.

In Definition 1(2), the idea of "favoring" is a notion of "partial causation." A transition "favors" an outcome if it keeps the outcome possible at least for a while; that is, although there is no thought that the transition guarantees the occurrence of the outcome, O, it does not render it henceforth impossible—as does every other immediate outcome of e.

4.1. Stit

The workhorse locution \"[α stit: Q]\" in FF, where α names an agent and Q is a sentence, signifies that the choice of the agent, α, guarantees the truth of Q (Positive condition) in circumstances in which Q is not already settled true (Negative condition). If we are speaking of a single choice, it needs observing that it must be seldom indeed that a single basic transition, \((e \rightarrow p_{\text{loc}}(h))\), can guarantee the truth of Q, unless Q reports, in effect, an immediate outcome of e, a case that I first consider.

I rely on the fundamental truth locution, \(S, J, e, c, e, h \models A\), pertinent to the "internal standpoint" of Section 3.2. The only difference from FF is the move from the moments of branching time to the point events of BST. The account of stit is structurally the same.

\(S, J, e, c, e, h_1 \models [\alpha \text{ stit: Q}] \iff e \in \alpha \text{ and } S, J, e, c, e, h_2 \models Q \text{ for all } h_2 \text{ such that } h_1 \equiv h_2 \text{ in the sense of Section 2(2)}\) (Positive condition), and \(S, J, e, c, e, h_2 \not\models Q \text{ for some } h_2 \text{ such that } e \in h_2 \) (Negative condition).

This is the dstit of FF and [13], which looks better in branching time than in branching space–times, since in the former case, originating causes must be linearly ordered. When, however, we consider many causae causantes based on many past causal loci in Our World, it is forced upon us that the various pcls are likely to be spread out, some pairs having a space-like relation, and other pairs a causal relation. It's not easy to see the point of collapsing this wealth of structure into the framework, which was predicated on a space–times is more narrowly focused than the companion story of FF about stit in branching time: The Q in \([\alpha \text{ stit: Q}]\) took the place of an arbitrary sentence, which could express an arbitrary proposition, but Definition 2, in contrast, explains "seeing to it that in virtue of a system of prior choices" only for outcome events, and indeed only for outcome chains, the easiest case of all, and so derivatively only for rather simple outcome propositions.

The system of causae causantes is in certain dimensions much less limiting than that of FF, and that not only because of the move from branching time to branching space–times. I can illustrate what I mean while staying entirely in the branching-time framework. The scheme of FF is defective to the extent that there is no way to represent an outcome as caused by a succession of contributory causes. There is no way to say that Mary saw to it that the dishes were washed by carrying out a sequence of choices: First she chose to do the silverware at moment m₁, then the plates at m₂, and, finally, the serving dishes at m₃. The scheme of FF permits only the last to count, the others being redundant just by being causally
earlier and hence already causally implied by the occurrence of that final outcome. The thought is not that in general choosing to wash the serving dishes implies having previously chosen to wash the plates. Instead, since histories are closed downward, there is a bare geometric fact: That the final choice point, $m_3$, occurs in a history, $h$, implies as a “historically necessary condition” not only that $m_2$ (which was postulated as earlier that $m_2$) also occurs in $h$, but furthermore that an outcome chain, $O$, representing the outcome of the plates choice at $m_2$, also occurs in $h$. That’s because there (probably) is a unique immediate outcome of $m_2$ that favors $m_3$.

The present analysis overcomes this severe defect by not looking at mere outcomes ($silverware washed, plates washed, and serving dishes washed$), but by instead looking at the basic transitions, $(m_1 \rightarrow silverware-washed), (m_2 \rightarrow plates-washed),$ and $(m_3 \rightarrow serving-dishes-washed)$. It is those transitions which, when properly understood, are each an irredundant necessary condition of her washing the dishes. Those transitions, taken together, form a set of INNS conditions (INNS rather than INUS because, in this example, not disjunctive).8

All is not, however, plain sailing. It remains natural to ask when Mary washed the dishes. If the question is asked rhetorically as part of an effort to cast doubt on BSTAC theory, the defensive response is to remind the questioner that we are dealing with transitions, and that we have all known from the beginning that transitions, to use an apt expression coined by a famous Philosopher, have no “simple location.” To suppose otherwise is to commit Whitehead’s “fallacy of simple location.” One might suggest that it is unlikely to be fruitful to inquire into, for example, “the time of a killing.” That negative-minded suggestion may well have, however, a variety of interesting counters. I leave the matter in this open state.

5. Many agents

One agent is hardly enough to populate Our World: The theory must provide for many agents. This is a complicated matter, needing additional research. Here I say just a few easy things.

Let us think of the joint representation of two or more agents. The thought comes to mind that two agents might share a life event. I think, however, that no good will come of tracing out the consequences of this thought. It is just too weird, too spooky. Not that it might not happen; it’s just that if it does happen, present thinking is not likely to help clarify the matter. I therefore enter the following.

Postulate 5 (No agent overlap). Agents never overlap: $\forall a_1 \forall a_2 (a_1, a_2 \in Agent \& a_1 \neq a_2 \rightarrow (a_1 \cap a_2) = \emptyset)$.

The postulate says, in effect, that the “world lines” of two agents cannot intersect. It is something like “no two material objects in the same place at the same time,” and perhaps that observation is enough to raise the comfort level of the postulate.

Agent is somewhat like an “absolute concept” in the sense of Bressan [10]: If you are given a life event, $e$, there is a unique member of Agent of which $e$ is a part. In other words, if $(a_1 \cap a_2) \neq \emptyset$ then $a_1 = a_2$.

It is easy to say, from the external standpoint, that a group of agents is entirely responsible for $O$:

Definition 3 (Group stit). Provided $\Gamma \subseteq Agent$, $(\Gamma \text{ stit } O)$ iff $\emptyset \neq pcl(O) \subseteq \bigcup \Gamma$.

Thus one can see that the apparatus of pcls and causae causantes makes it effortless to move from saying that the occurrence of $O$ is entirely the doing of a single agent, $a$, to saying that the set of agents, $\Gamma$, is fully responsible for the occurrence of $O$.9 Even so, although it is easy to say, one would have to choose $O$ carefully in order to have an example that rang true. Idealization will have to play a role in applying any of these stit concepts. There are a variety of such examples to be found in FF, and although worked out there in branching time, given enough leeway for idealization, there should be no problem in transporting them to BSTAC. In contrast, the analogous favoring concepts should have wide application, the point being that virtually all we “do” requires the “cooperation” of other agents, and of nature as well. (Please put the blame for this on Our World, not on me.)

5.1. Message sending and receiving

To put in relief one aspect of group responsibility, one would expect that there be communication among members of the group. What can the theory of branching space–times say about communication, while still holding to its policy of foregoing mental concepts, which are inevitably loose? What, that is, can we say about the causal underpinnings of sending and receiving and acting upon messages?

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7 To be fit for service in INNS and INUS conditions, it unexpectedly turns out that a transition should be taken to “occur” just when if the initial occurs, then so does the outcome—with the “if—then” understood as a material (truth-functional) implication!

8 FF aimed at something like this with the “transition stit” of Chapter 8G.3, but that section entirely missed the mark, and should be consigned to the proverbial flames.

9 Definition 3 would need to be amended if one wished to prohibit “free riders” and the like. Chapter 10 of FF should be consulted.
It seems right that a theory of communication should be developed against an indeterministic causal background, and that for several reasons: (1) There is the question of “noise,” construed as randomly generated. (2) Sending a message ought to involve choice. I hope you agree that in the present context automated “message-sending” systems are beside the point. (3) Choice is also involved in receiving a message. I have in mind what J. Thomson calls “uptake.” At the very least, the receiver has to choose to prepare for the reception. (4) And if the message is to be “effective,” it should contribute causally to the receiver’s taking some action. The theory of probabilities in branching space–times (as in Placek [24] and, especially, Müller [20] and Weiner and Belnap [29]) would doubtless play an important role in the theory of message-passing. Stable, detailed considerations on this topic remain to be developed.

6. Norms

This essay was initially conceived as being concerned with norms in branching space–times, and that remains the principal aim of the research of which it is the product. There turned out to be, however, so much required in the way of preliminary conceptual analysis that I have had to shrink what I have to say explicitly about norms to negligible proportions. This accounts for my labeling this essay as a “prolegomenon.”

BSTACN (BSTAC with norms) postulates generated norms, that is, norms that are generated by a particular localized act of an agent. Wansing [28] has studied such norms in the context of branching time, with the stick apparatus, emphasizing the dual roles of the giver and receiver of obligations as agents, etc. Also FF has several chapters that consider norms in branching time, and Müller [21] makes yet further advances. Here my remarks find their basis in “double time references” as described in FF (see the index of FF) and Belnap [2] (DTR). The norm-generating act might be the making of a promise, the laying on of an obligation, the issuing of an invitation, etc. Say that the norm has been violated, and appropriate sanctions are due. Perhaps instead)

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7. Summary

Here, briefly, is where we have been.

The underlying rationale for this essay given in Section 1 is that norms require agents and indeterminism, that generated norms reference choice events that influence only the causal future, and that an account of norms should give due consideration to space-like-related agent choices. A “branching space–times” (BST) structure that is indeterministic, relativistic, and has room for agents seems to be required. Although not obvious in this largely informal essay, complete mathematical rigor is imposed as a constraint on BST theory.

From previous work on BST, I emphasize in Section 2 the ontology of point events and a causal ordering that is a common generalization of the orderings of special relativity and of “branching times.” BST theory is a story about “events.” A “history” is defined as, in effect, a maximal consistent set of (not propositions but) point events; histories carry the modal burden of BST in strict analogy to “possible worlds” theory (but it’s only an analogy). Defined kinds of events include initial events, outcome events, transition events, and among the latter, basic “immediate” transitions, which can serve as originating causes, or causae causantes. An initial of a causae causantes of an outcome event is called a “past causal locus,” and the set of causae causantes of an outcome event provably form a set of INUS conditions in Mackie’s sense: Each is an insufficient but non-redundant part of an unnecessary but sufficient condition of the occurrence of the outcome.

An ontology of agents is forthcoming in Section 3, yielding the theory “BSTAC” (branching space–times with agents and choices). An agent is represented in BSTAC as a kind of tree, each branch of which is a continuous chain of point events, from birth to death, in some history. Given an agent, such a chain is called a “life history,” and is conceived as consisting in point-like “life events.”

As indicated in Section 4, of principal interest with respect to some outcome are those of its past causal loci that are part of the agent. A choice made by an agent might or might not “favor” a certain outcome. When all past causal loci of an outcome lie within the agent, since the agent contains a complete set of INUS conditions for the outcome, we say that the agent “sees to it that” [stit] the outcome occurs, thus making contact with earlier work on agents in branching time.

There is in Section 5 a brief discussion of multiple agents, including the observation that distinct agents never overlap in BST, and that generalizing “stit” to a group of agents is straightforward. This idea of a “group stit” is, however, weak. It could be somewhat strengthened (without violating the “no loose mental talk” constraint on BSTAC theory) by the notion of “message passing,” which can have an entirely objective account in BSTAC.

Section 6 hints at a theory of norms generated by choices of an agent, for example, the norm that is generated by the making of a promise. The essay advances the thesis that understanding something like a promise requires the ability of BSTAC to handle correctly the “double time reference” involved in saying that a promise made at an earlier point event has (or hasn’t) been carried out at a later point event. Finally, the essay suggests that in describing a norm generated by, for example, a promise, one wants to combine double time references with the austere theory of “strategies” of FF, Chapters 13 and 14.

Uncited references

[15] [19] [23] [25] [27]

References


